Machine Design-I
BME-26

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Lecture Schedule

5 Credit (3L-1T-2P)

Day	Time	Lecture/Tutorial	
Monday	11:20 AM-12:15 PM (3^{rd})	Lecture	1
Wednesday	10:30 AM-11:20 PM (2^{nd})	Lecture	2
Thursday	11:20 AM-12:15 PM (3^{rd})	Lecture	3
Friday	3:20 PM-4:10 PM (6^{th})	Tutorial	4

Syllabus

UNIT-I

Introduction

- Definition, Design requirements of machine elements, General design procedure, Introduction to Design for Manufacturing, Interchangeability, Limits, Fits and Tolerances, Standards in design, Selection of preferred sizes.

Engineering materials and their properties

- Classification, Mechanical properties, Ferrous and non-ferrous metals, Nonmetallic materials, Indian Standards designation of carbon & alloy steels, Selection criteria of materials.

UNIT-II

Design under Static Load

- Modes of failure, Factor of safety and basis of determination, Principal stresses, Torsional and bending stresses, Principal stresses in design of machine element, Theory of failure, Eccentric loading.

Design under Variable Loads

- Cyclic stresses, Fatigue and endurance limit, Factors affecting endurance limit, Stress concentration factor, Stress concentration factor for machine components, Notch sensitivity, Design for finite and infinite life, Soderberg, Goodman & Gerber criteria.

Syllabus

UNIT-III

Design of Joints

- Design of threaded joints, Preload on the bolt, stiffness of bolt and members, efficiency of joints; Design of weld joints, Specification of welds, weld design under different loading conditions, Design of riveted joints.

Cotter and Knuckle Joint

- Types of cotter joints, Design of socket and spigot cotter joint, Gib and cotter joint, Design of knuckle joint

UNIT-IV

Design of Shafts

- Cause of failure in shafts, Materials for shaft, Stresses in shafts, Design of shafts subjected to twisting moment, bending moment and combined twisting and bending moments, Shafts subjected to fatigue loads, Design for rigidity

Keys and Couplings

- Types of keys, splines, Selection of square & flat keys, Strength of sunk key, Couplings-Design of rigid and flexible couplings

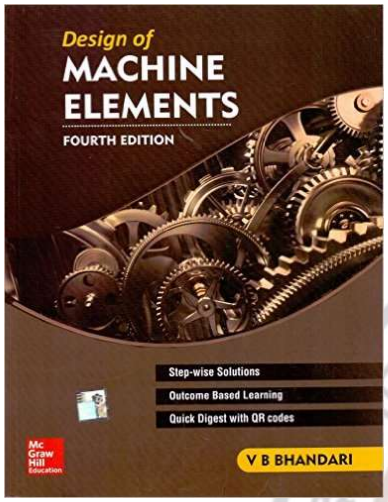
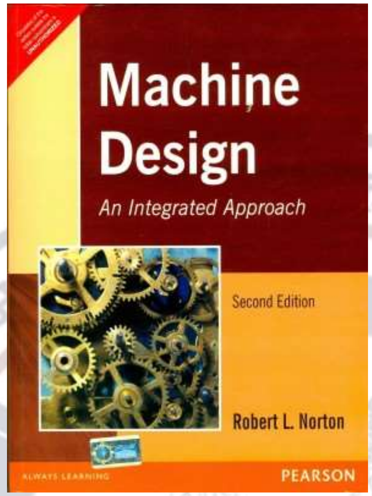
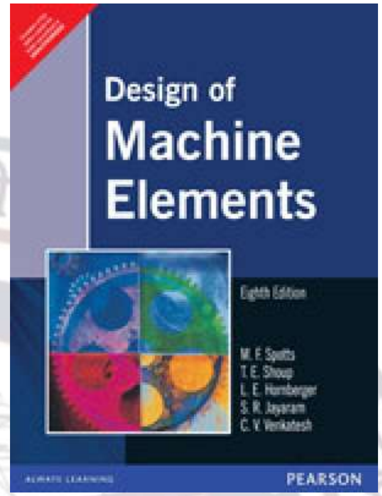
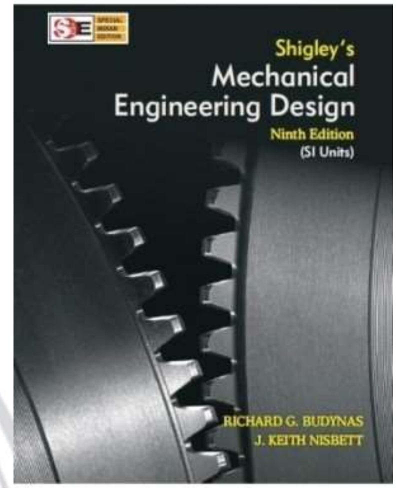
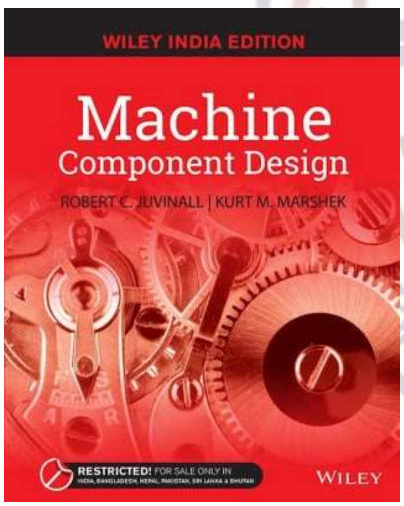
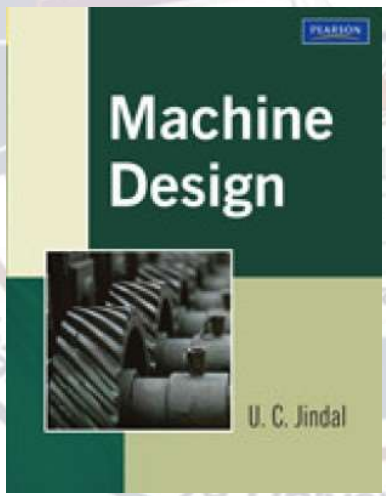
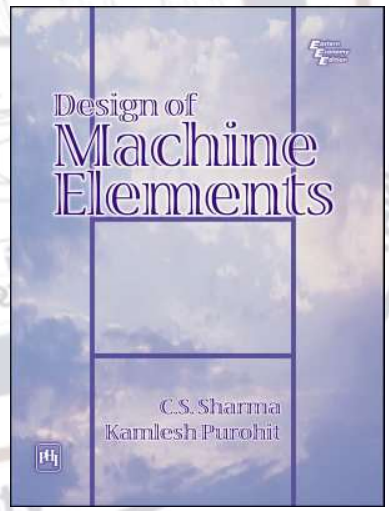
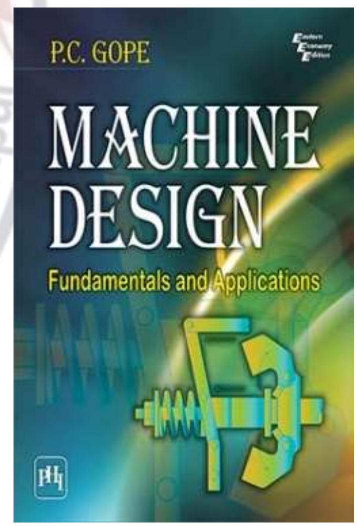
Text/Reference Books

Text Books

- Design of Machine Elements-V. B. Bhandari (Tata McGraw Hill)
- Mechanical Engineering Design – Joseph E. Shigley (McGraw Hill)
- Fundamentals of Machine Components Design – Juvinall (Wiley)

Reference Books

- Mechanical Design of Machine Components – Norton (Prentice Hall)
- Design of Machine Members - Alex Valance and VI Doughtie (McGraw Hill)
- Machine design-M.F. Spott (Prentice Hall India)
- Machine Design-Maleev and Hartman (CBS)
- Machine design -Black & Adams (McGraw Hill)
- Machine Design-Sharma and Agrawal (S.K. Kataria & Sons)


Design of
MACHINE ELEMENTS
FOURTH EDITION
Step-wise Solutions
Outcome Based Learning
Quick Digest with QR codes
V B BHANDARI

Machine Design
An Integrated Approach
Second Edition
Robert L. Norton
PEARSON

Design of
Machine Elements
Eighth Edition
M. F. Spotts
T. E. Shoup
L. E. Hornberger
S. R. Jayaram
C. V. Venkatesh
PEARSON

Shigley's
Mechanical
Engineering Design
Ninth Edition
(SI Units)
RICHARD G. BUDYNAS
J. KEITH NISBETT

WILEY INDIA EDITION
Machine
Component Design
ROBERT C. JUVINALL | KURT M. MARSHEK
RESTRICTED! FOR SALE ONLY IN
WILEY

Machine
Design
U. C. Jindal

Design of
Machine
Elements
C.S. Sharma
Kamlesh Purohit

P.C. GOPE
MACHINE
DESIGN
Fundamentals and Applications

Marks Distribution

S.No.	Assessment Basis		Duration	Marks
1.	Continuous Evaluation	Minor Test-I	1 Hour	20
2.		Tutorial/Attendance/ Home Assignment/Quiz	-	10
3.	Practical Work/Records/Viva Voce/ Practical Examination		-	20
4.	Major Theory Examination		3 Hours	50

Note: Design data book is allowed in Minor/Major Examinations

Evaluation

- Minor Test
- Major Theory Examination

Attendance >75% (including medical emergencies)

- Tutorials: Solve and submit in each class
- Assignments: Solve later and submit it in the next class

Note:- Tutorial and Assignments to be submitted on A4 size papers.

Machine Design-I

Course category: Department Core (DC)

Pre-requisites: Mechanics of Solids (BME-14)

Course Outcomes: The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course

- The understanding of design of mechanical components/systems, associated design parameters and standards, and knowledge of engineering materials and their properties.
- The ability to design mechanical components under the static loads and dynamic loads based on different criteria.
- The ability to design temporary and permanent joints such as riveted, bolted and welded joints as well as design of cotter and knuckle joints and its engineering applications.
- The knowledge of design of circular shafts under the combined loadings, selection of keys, and design of rigid & flexible couplings.

Machine Design–I Lab

Note: Minimum **Eight** experiments are to be performed from the following. Students are advised to use design data book for the design. Drawing shall be made wherever necessary on small drawing sheets

1. Design of machine components subjected to steady loads
2. Design of machine components subjected combined steady and variable loads
3. Design of boiler riveted joint
4. Design of eccentrically loaded riveted joint
5. Design & drawing of Cotter joint
6. Design & drawing of Knuckle joint
7. Design of shaft for combined constant twisting and bending loads
8. Design of shaft subjected to fluctuating loads
9. Design and drawing of flanged type rigid coupling
10. Design and drawing of flexible coupling

UNIT-I, Part-1

Introduction

- Definition,
- Design requirements of machine elements,
- General design procedure,
- Introduction to Design for Manufacturing,
- Interchangeability, Limits, Fits and Tolerances,
- Standards in design,
- Selection of preferred sizes.

Problem Solving and Machine Design

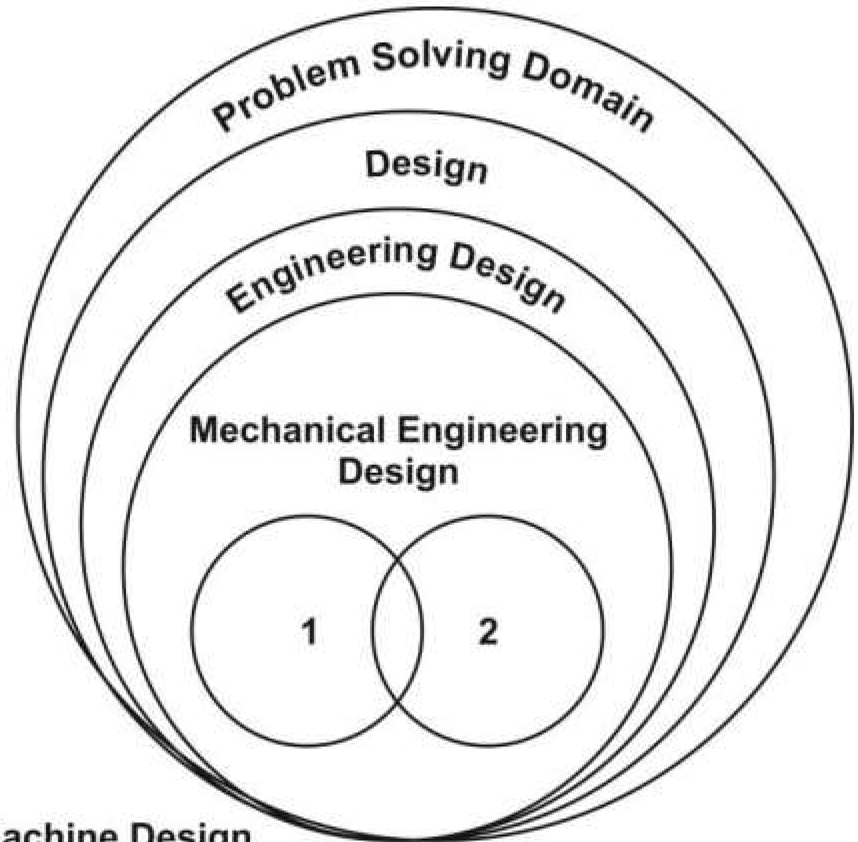
- The domain of problem solving is very large because in addition to design, it includes solving problems in diverse areas such as legal, medical, political and social.
- Similarly, the domain of design is also very wide spread because it includes architectural design, engineering design, fashion design and interior design.
- Similarly, engineering design would include design in the disciplines of civil engineering, electrical engineering, electronics engineering, instrumentation and control engineering and mechanical engineering.

Problem Solving and Machine Design

Mechanical engineering design has two important streams:

- Machine design where the focus is the transfer of motion and mechanical power.
- Energy conversion and transfer systems where the focus is energy conversion, energy generation, heat transfer, thermodynamics and combustion.

Venn diagram for Machine Design as a subset of problem solving domain



1. Machine Design
2. Design of Energy Conversion Systems

Engineering Design

- Engineering design may be defined as the iterative decision making activity to create a plan or plans by which the available resources are converted, preferably optimally, into systems, processes or devices to perform the desired functions and to meet human needs.

- “An iterative decision making process to conceive and implement optimum systems to solve society’s problems and needs.”

Mechanical Engineering Design

- If the end product of the engineering design can be termed as mechanical then this may be termed as Mechanical Engineering Design.

- "Mechanical Engineering Design is defined as iterative decision making process to describe a machine or mechanical system to perform specific function with maximum economy and efficiency by using scientific principles, technical information, and imagination of the designer."

Blooms Taxonomy

In a 1-To-1 Laptop Learning Environment, memorizing facts is Pointless!
If you need a fact - just *Google* it!
When you *USE* facts, you remember them!

New Version

In 1956, Benjamin Bloom headed a group of educational psychologists who developed a classification of levels of intellectual behavior important in learning. During the 1990's a new group of cognitive psychologist, lead by Lorin Anderson (a former student of Bloom's), updated the taxonomy reflecting relevance to 21st century work. The graphic is a representation of the NEW verbage associated with the long familiar Bloom's Taxonomy. Note the change from Nouns to Verbs to describe the different levels of the taxonomy.

Note that the top two levels are essentially exchanged from the Old to the New version.

Old Version

Remembering: can the student recall or remember the information?	define, duplicate, list, memorize, recall, repeat, reproduce state
Understanding: can the student explain ideas or concepts?	classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase
Applying: can the student use the information in a new way?	choose, demonstrate, dramatize, employ, illustrate, interpret, operate, schedule, sketch, solve, use, write.
Analyzing: can the student distinguish between the different parts?	appraise, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test.
Evaluating: can the student justify a stand or decision?	appraise, argue, defend, judge, select, support, value, evaluate
Creating: can the student create new product or point of view?	assemble, construct, create, design, develop, formulate, write.

Design Requirement of Machine Elements

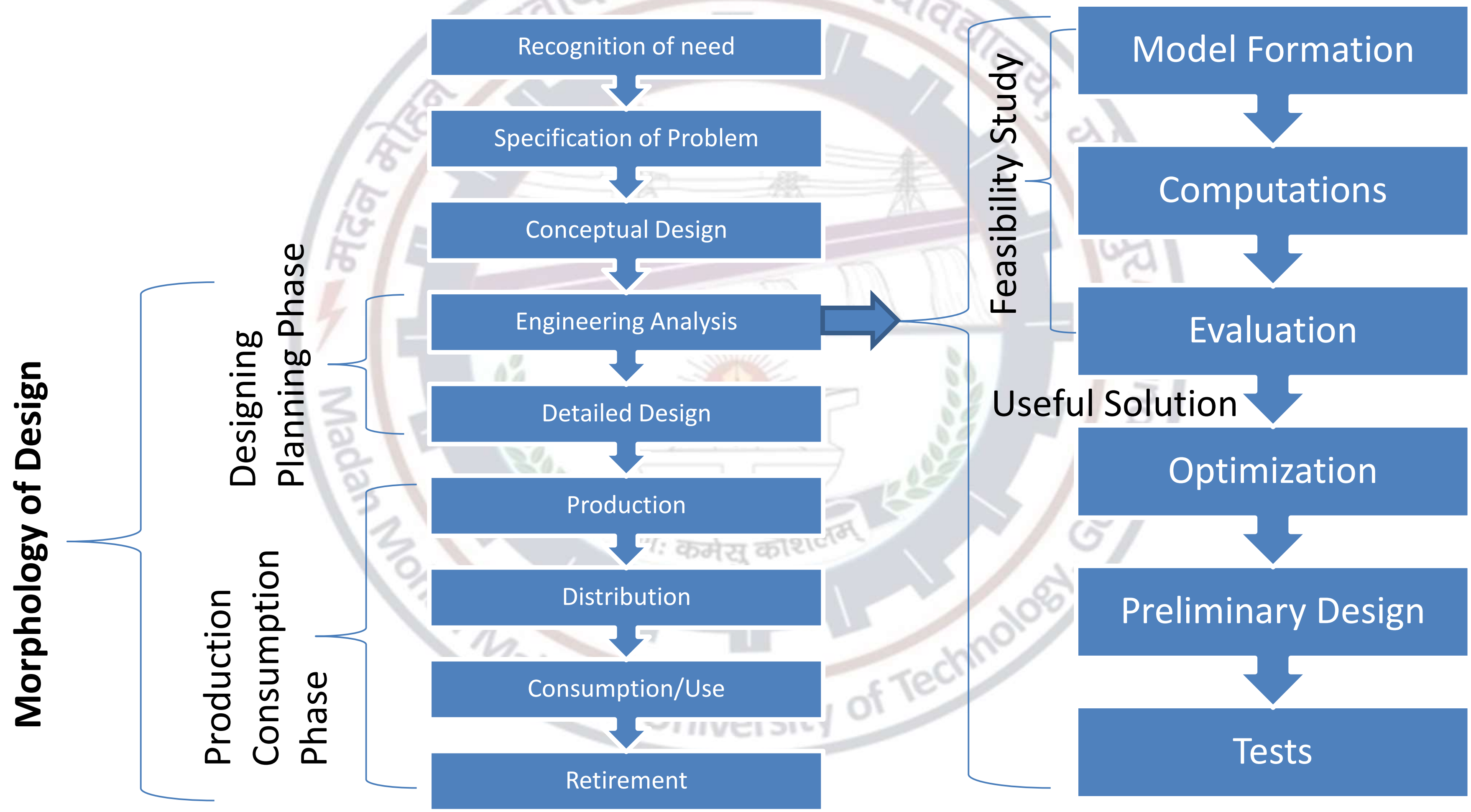
- A part of a machine that has motion relative to some other parts is called a machine element. Some machine elements may consist several elements; e.g., a ball bearing is a machine element and it consists an inner race, spherical balls, a retaining cage and an outer race.
- A machine is as strong and reliable as its weakest element. Remember, a chain breaks at its weakest, link. Same is true for machine element.
- The design requirement of a machine element is to ensure that it performs according to the specifications during its stipulated life span. In order to achieve the desired performance, the machine elements should satisfy the following important requirements:

Strength, Rigidity , Wear resistance , Corrosion resistance, Ease of lubrication Minimum dimensions, weight and power loss in friction, Safety, Reliability Manufacturability, Maintainability, Conformance to specifications and standards, Minimum initial and life-cycle cost, Minimum Liability and Warranty Cost, Possibility of Recycling after its useful life.

Factors to be considered in Machine Design

- What device or mechanism to be used? This would decide the relative arrangement of the constituent elements.
- Material
- Forces on the elements
- Size, shape and space requirements. The final weight of the product is also a major concern.
- The method of manufacturing the components and their assembly.
- How will it operate?
- Reliability and safety aspects
- Inspectability
- Maintenance, cost and aesthetics of the designed product.

Design Procedure

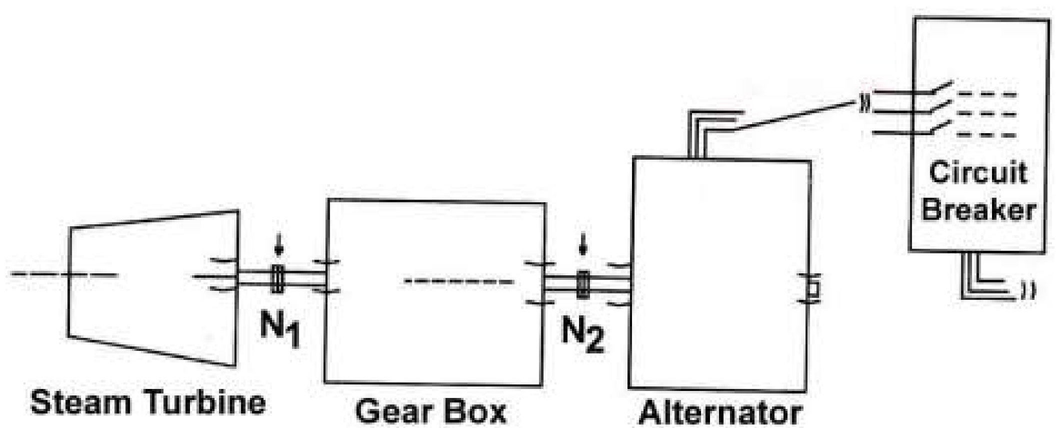


Design of Machine Elements

Let us consider the case of steam-driven alternator. Assume that we have to design the couplings and gear box. The steam turbine and alternator are supplied by our vendors.

What information do we need to start the design: speed and power rating? Or what else?

Speed of steam turbine, N1 = 9000 rpm, Speed of alternator N2 = 750 rpm, Power rating = 3.5 MW



Design of Machine Elements (Contd.)

How do we now develop detailed specifications of the two couplings and the gear box?

Each element will need specifications- say what type of couplings? Rigid or flexible; if flexible- what limits of torsional flexibility? It is desirable to have a design procedure similar to the one discussed above

Specify the functions of the element being designed

- Determine the value working parameter such as forces, moments, speed, etc. and also the values in extreme cases. For example what happens if there is a short circuit after the circuit breaker? Normal safety features. Also the forces and moments-say on the foundation bolts of the gear box.
- Determine failure mode of each element.
- Select suitable material and the allowable stresses
- Calculate dimensions from the view of strength and life required; check for assembly, maintenance and manufacturing. Specify appropriable tolerances
- Check the design at all the critical sections and critical situations
- Revise if needed optimize the design
- Prepare working drawings

Design of Machine Elements (Contd.)

- Many machine elements are selected from the catalogues of manufacturers. In the above examples, couplings, bearings, keys and fasteners would perhaps be procured from the respective manufacturers of each element.

- In order to ease sourcing, standards for such machine elements have been published by the Bureau of Indian Standards.

- However, appropriate selection of couplings and the detailed design of gear box will be the responsibility of designer. Design and selection of couplings is dealt with-in this semester; design of bearing and gears is the subject matter of next semester.

Standards and Standardization

Standards in Design:

- Standard is a set of specifications, defined by a certain body or an organization, to which various characteristics of a component, a system, or a product should conform. The characteristics may include: dimensions, shapes, tolerances, surface finish etc.
- The objective of a standard is to reduce the variety and limit the number of items to a reasonable level.
- A code is defined as a set of specifications for the analysis, design, manufacture, testing and erection of a product. The objective of a code is to achieve a specific level of safety.

Types of Standards used in Machine Design

Based on the defining bodies or organization, the standards used in the machine design can be divided into following three categories:

(i) **Company Standards**: These standards are defined or set by a company or a group of companies for their use.

(ii) **National Standards**: These standards are defined or set by a national apex body and are normally followed throughout the country. Like BIS, AWS.

(iii) **International Standards**: These standards are defined or set by international apex body and are normally followed throughout the world Like ISO, IBWM.

Advantages of Standards

Advantages:

- Reducing duplication of effort or overlap and combining resources
- Bridging of technology gaps and transferring technology
- Reducing conflict in regulations
- Facilitating commerce
- Stabilizing existing markets and allowing development of new markets
- Protecting from litigation

Selection of Preferred Sizes

- French balloonist and Engineer Charles Renard suggested the method to specify the sizes of the product to satisfy the needs of the customers with the minimum number of sizes in the given range by using the G.P. He gave the five basic series having their specific series factor as follows:

SERIES	SERIES FACTOR
R-5	$\sqrt[5]{10}$
R-10	$\sqrt[10]{10}$
R-20	$\sqrt[20]{10}$
R-40	$\sqrt[40]{10}$
R-80	$\sqrt[80]{10}$

The second size is obtained by multiplying the series factor to the first size. The third size is obtained by multiplying the series factor to the second size. And this procedure is repeated until the whole range is covered. Thus the sizes are specified in the given range and this is known as the selection of preferred sizes.

Advantages of Selection of Preferred Series

- The differences in two successive terms have a fixed percentage.
- Provides small steps for small quantities and large steps for the large quantities. It is in conformance with the mode of variation found in nature.
- The product range is covered with minimum number of sizes without restricting the choices of the customers.
- It helps the designer to avoid the selection of sizes arbitrarily.
- Example: Range of load carrying capacity = 15-100 kN, Specify 9 models in this range using R10 series?
- 16, 20, 25, 31.5, 40, 50, 63, 80 and 100 kN.

Design for Manufacturing and Assembly

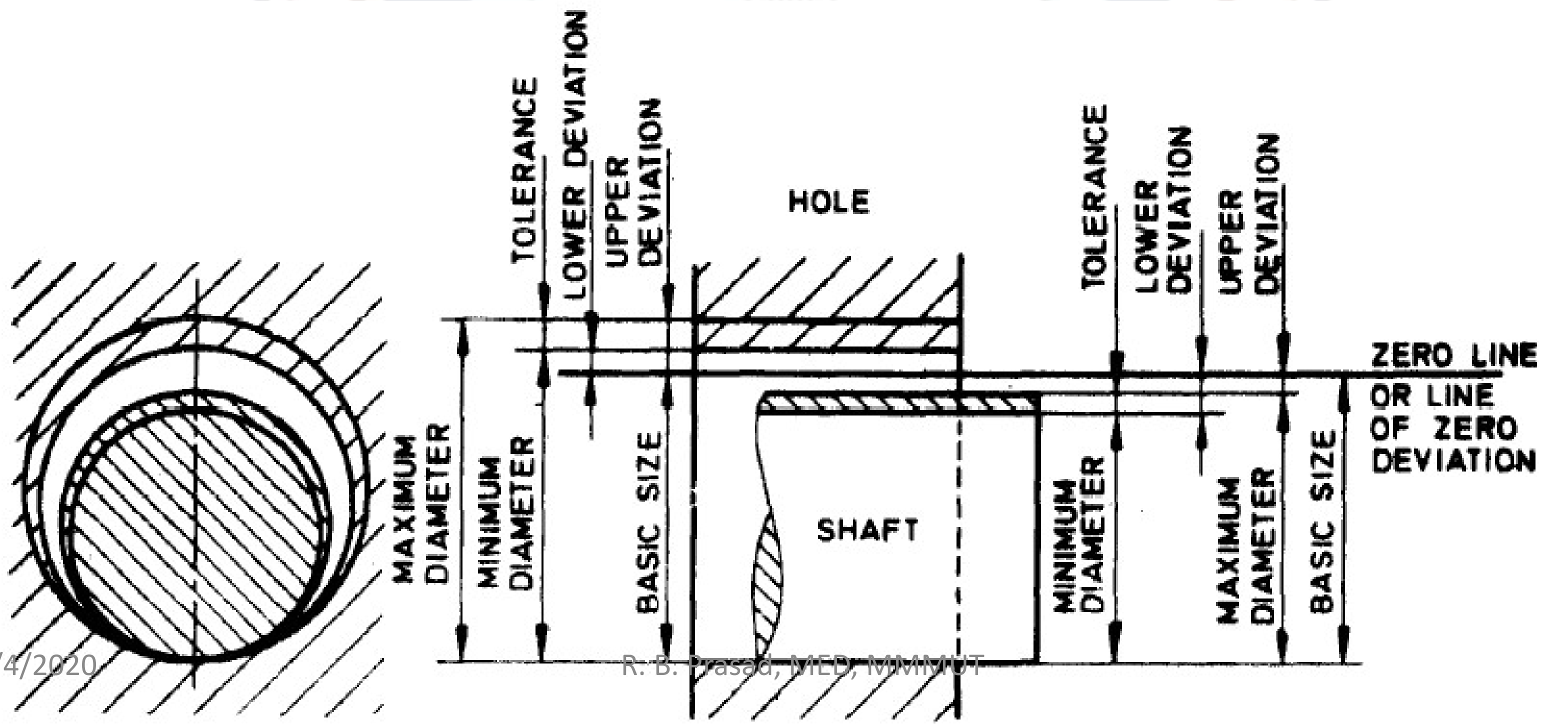
- Reduce the parts count
  - fewer parts, lower cost, simple assembly, less defects
- Use modular designs
  - reduces no. of parts being assembled, field service becomes simple, faster & cheaper
- Optimize part handlings
  - Parts should not become tangled, struck together, require special handling
- Assemble in the open
  - Manual assembly should be carried out in clear view
- Do not fight gravity
  - gravity should assist the assembly process, do not require special clamping fixtures
- Design for Part Identity
  - symmetric parts are easier to handle and orient
- Eliminate Fasteners
  - the cost of driving a screw can be six to ten times the cost of screw itself
- Design parts for simple assembly
  - added chamfers on both parts and adequate guiding surfaces make assembly faster and more reliable
- Reduce, Simplify and Optimise Manufacturing process

Limit, Fits and Tolerences

- **The standard reference temperature** is 20 C for industrial measurements and, consequently, for dimensions defined by the system.

- Due to the inevitable inaccuracy of manufacturing methods, a part cannot be made precisely to a given dimension, the difference between maximum and minimum limits of size is the **tolerance.**

- When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a **fit.**



Tolerance

- How to decide tolerance?
  - Functional requirements of mating parts
  - Cost of production
  - Available manufacturing process
    - Choose as coarse tolerance as possible without compromising functional requirements
    - Proper balance between cost and quality of parts

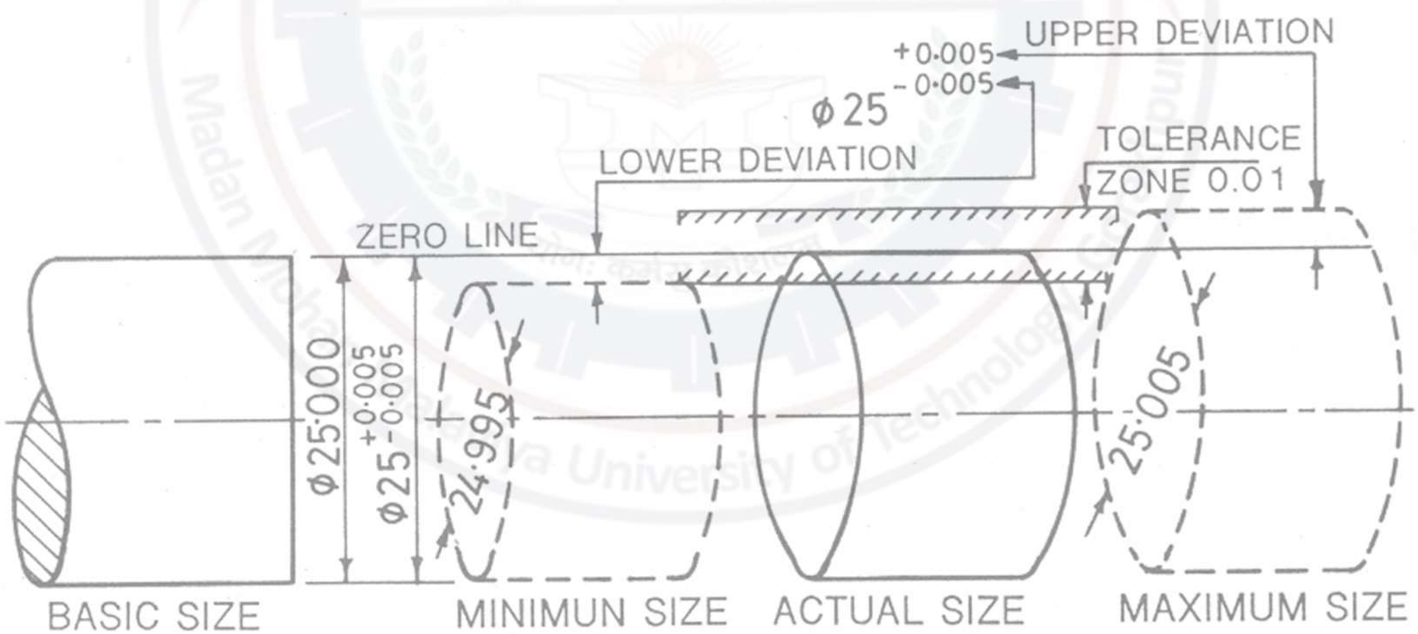
Basic Size, Upper and Lower Deviation

HOLE

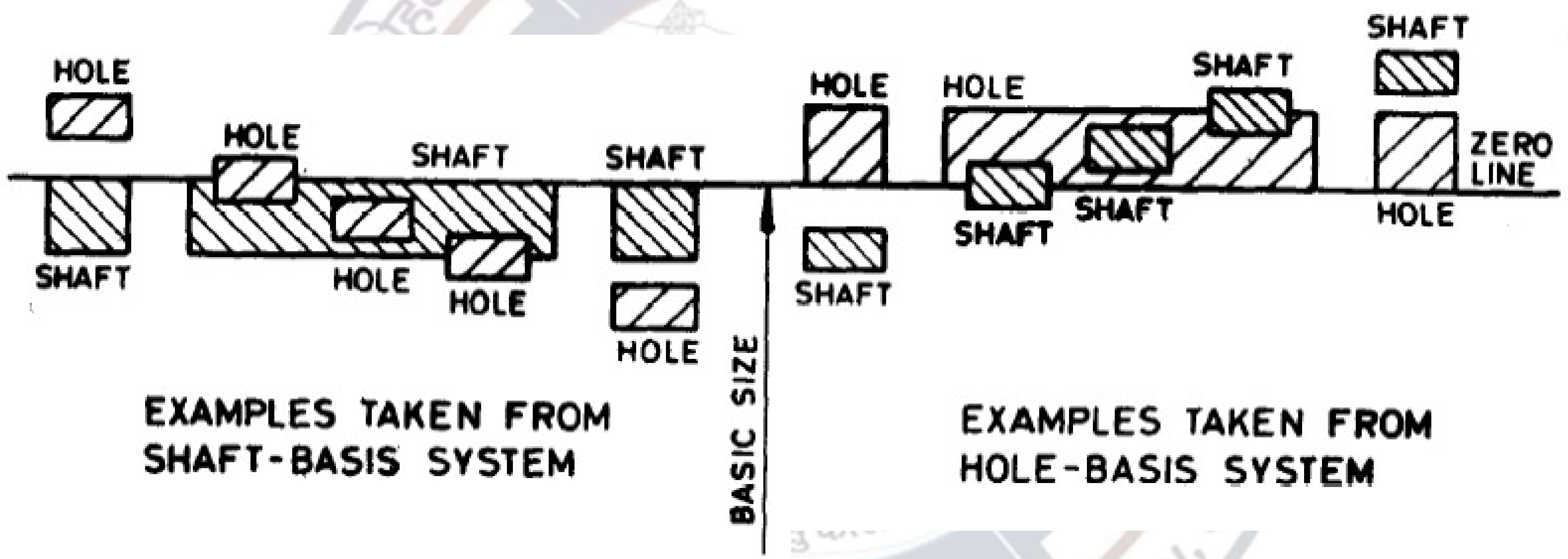
Max Hole size – Basic Size = Upper Deviation
Min Hole size – Basic Size = Lower Deviation

SHAFT

Max shaft size – Basic Size = Upper Deviation
Min shaft size – Basic Size = Lower Deviation



Hole basis and Shaft basis system



A fit is indicated by the basic size common to both components, followed by symbol corresponding to each component, the hole being quoted first.

E.g. 45 H8/g7

Representation of Tolerance

2) Number or Grade

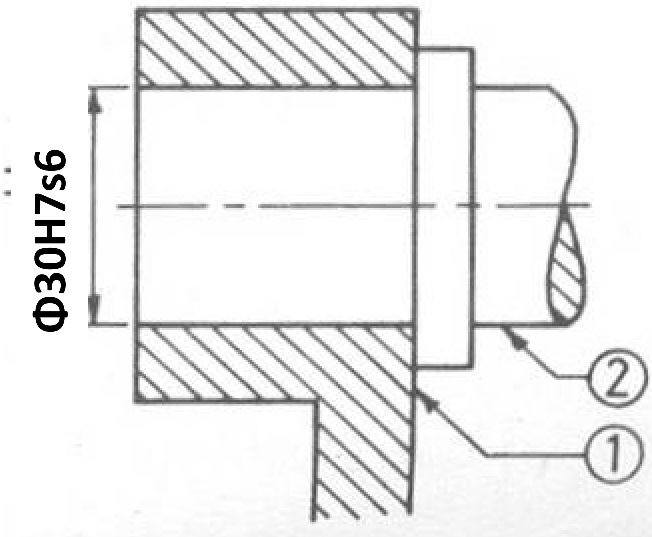
IT01, IT0, IT1,….IT16

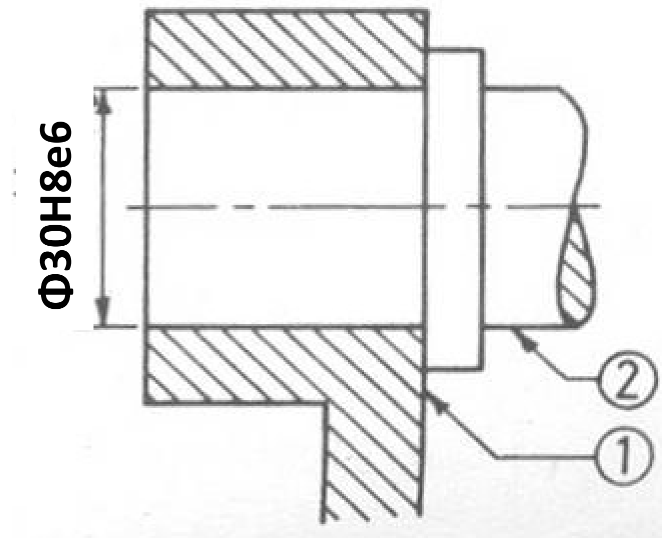
Tolerance Grade defines range of dimensions (dimensional variation)

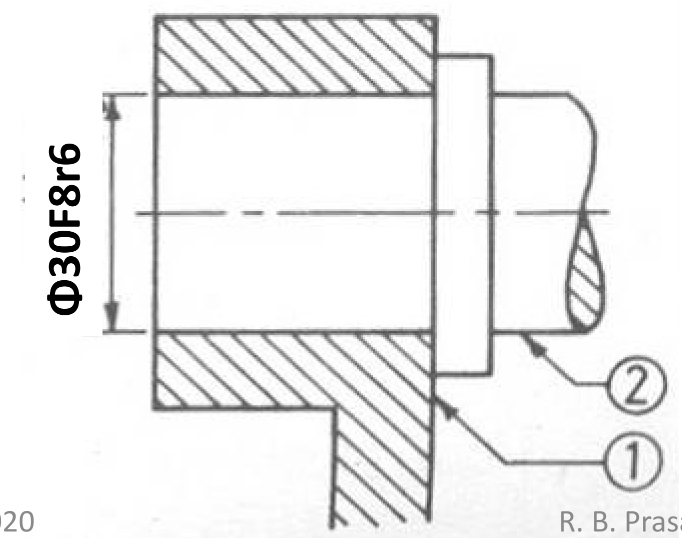
There are manufacturing constraints on tolerance grade chosen

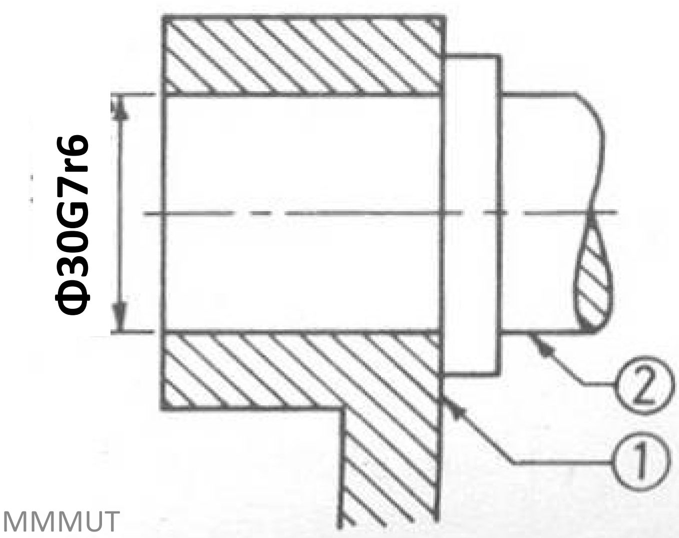
Tolerance grade	Manufacturing process and applications	Machine required
IT01, IT0 IT1 to IT5	Super finishing process, such as lapping, diamond boring etc. Use: Gauges	Super finishing machines
IT6	Grinding	Grinding machines
IT7	Precision turning, broaching, honing	Boring machine, honing machine
IT8	Turning, boring and reaming	Lathes, capstan and automats
IT9	Boring	Boring machines
IT10	Milling, slotting, planing, rolling and extrusion	Milling machine, slotting machine, planing machine and extruders
IT11	Drilling, rough turning	Drilling machine, lathes
IT12, IT13, IT14	Metal forming processes	Presses
IT15	Die casting, stamping	Die casting machine, hammer machine
IT16	Sand casting	—

Estimate kind of fit









FITS APPLICATIONS

Interference fit

Shring fit	H8/u8	Wheel steel tyres, bronze crowns on worm wheel hubs, couplings etc
Heavy drive fit	H7/s6	
Press fit	H7/r6	Coupling of shaft ends, bearing bushing in hubs, valve seats, gear wheels
Medium press fit	H7/p6	

Transition fit

Light press fit	H7/n6	gears and bearing bushes, shaft and wheel assembly fixed by feather key.
Force fit	H7/m6	parts of machine tools that must be dismantled without damage e.g. gears belt pulleys, couplings, fit bolts, inner rring of ball bearings
Push fit	H7/k6	belt pulleys, brake pulleys, gears and couplings as well as inner rings of ball bearngs on shafts for average loading conditions
Easy push fit	H7/j6	parts which are frequently dismantled, but are secured by keys, e.g. pulleys, hand wheels, bushes, bearing shells, piston on piston rods, change gear trains

Clearance fit		
Precision sliding fit	H7/h6	sealing rings, bearing covers, milling cutters on milling mandrels
Close running fit	H7/g6	sleeve shafts, clutches, movable gears in change gear trains
Normal running fit	H7/f7	Sleeve bearings with high revolution, bearings on machine tool spindles
Easy running fit	H8/e8	Sleeve bearings with mediuam revolution, greease lubricated bearings of wheel boxes, gear sliding on shafts and sliding blocks
Loose running fit	H8/d9	Sleeve bearings with low revolution
Slack running fit	H8/c11	Oil seals with metal housings, multi-spline shafts
	H11/a11	Large clearance and widely used

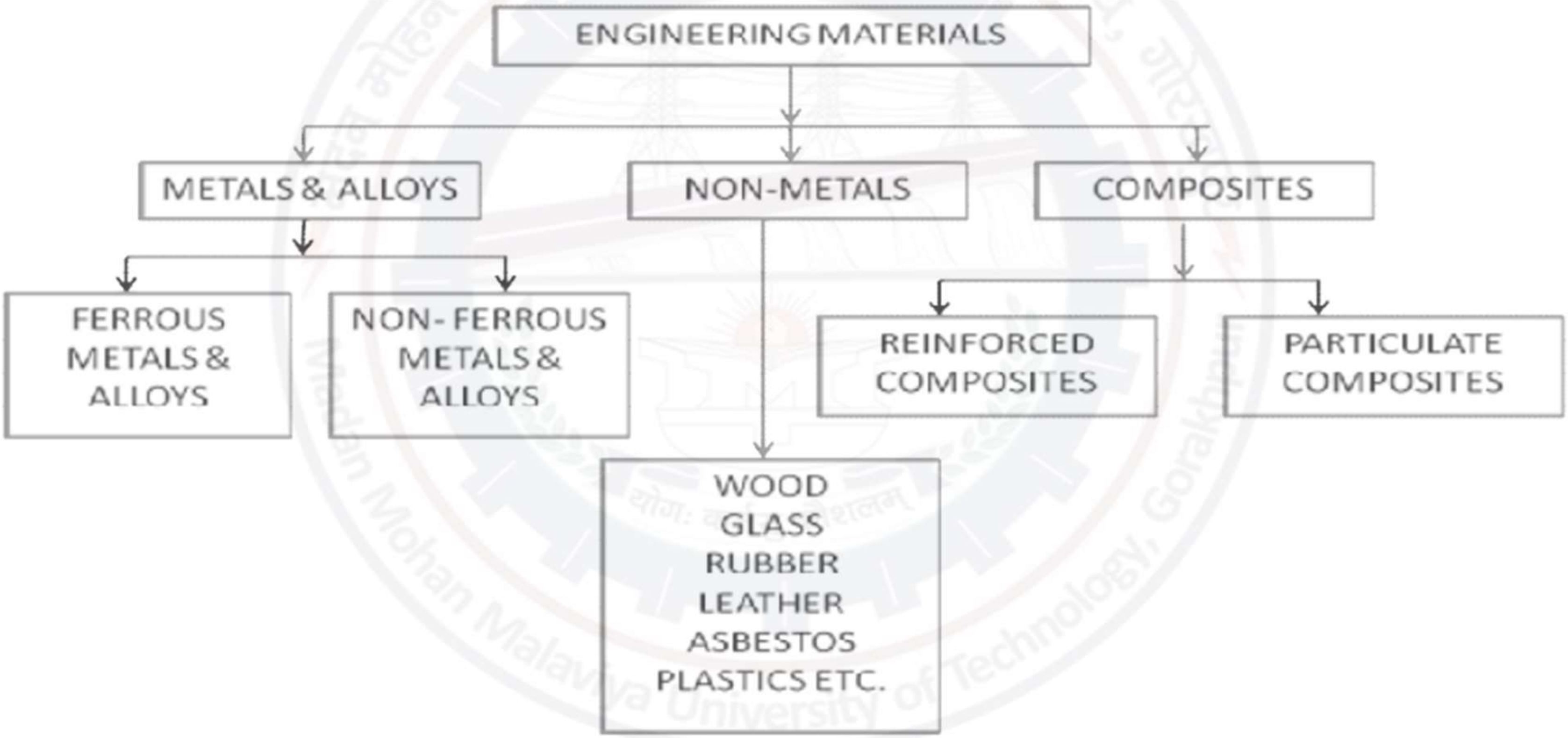
UNIT-I,
Part-2

Engineering Material and their properties

R. B. Prasad

Assistant Professor

CLASSIFICATION OF ENGINEERING MATERIALS



Ferrous Materials

Cast iron:

- It is an alloy of iron, carbon and silicon and it is hard and brittle.
- Carbon content may be within 1.7% to 3% and carbon may be present as free carbon or iron carbide Fe_3C.
- In general the types of cast iron are
  - (a) grey cast iron
  - (b) white cast iron
  - (c) malleable cast iron
  - (d) spheroidal or nodular cast iron
  - (e) austenitic cast iron
  - (f) abrasion resistant cast iron.

Cast iron

- Grey cast iron: Carbon here is mainly in the form of graphite. This type of cast iron is inexpensive and has high compressive strength. Graphite is an excellent solid lubricant and this makes it easily machinable but brittle. Some examples of this type of cast iron are FG20, FG35 or FG35Si15.
- White cast iron: In these cast irons carbon is present in the form of iron carbide (Fe3C) which is hard and brittle. The presence of iron carbide increases hardness and makes it difficult to machine. Consequently these cast irons are abrasion resistant.
- Malleable cast iron: These are white cast irons rendered malleable by annealing. These are tougher than grey cast iron and they can be twisted or bent without fracture. They have excellent machining properties and are inexpensive. Malleable cast iron are used for making parts where forging is expensive such as hubs for wagon wheels, brake supports.

Cast iron

- Spheroidal or nodular graphite cast iron: In these cast irons graphite is present in the form of spheres or nodules. They have high tensile strength and good elongation properties.
- Austenitic cast iron: Depending on the form of graphite present these cast iron can be classified broadly under two headings:
  - Austenitic flake graphite iron; and
  - Austenitic spheroidal or nodular graphite iron
- These are alloy cast irons and they contain small percentages of silicon, manganese, sulphur, phosphorus etc. They may be produced by adding alloying elements viz. nickel, chromium, molybdenum, copper and manganese in sufficient quantities. These elements give more strength and improved properties. They are used for making automobile parts such as cylinders, pistons, piston rings, brakedrums etc.
- Abrasion resistant cast iron: These are alloy cast iron and the alloying elements render abrasion resistance.
- Wrought iron: This is a very pure iron where the iron content is of the order of 99.5%. It is produced by re-melting pig iron and some small amount of silicon, sulphur, or phosphorus may be present. It is tough, malleable and ductile and can easily be forged or welded. It cannot however take sudden shock. Chains, crane hooks, railway couplings and such other components may be madeof this iron.

Steel

- This is by far the most important engineering material and there is an enormous variety of steel to meet the wide variety of engineering requirements.
- Steel is basically an alloy of iron and carbon in which the carbon content can be less than 1.7% and carbon is present in the form of iron carbide to impart hardness and strength.
- Two main categories of steel are
  (a) Plain carbon steel
  (b) Alloy steel

Steel

- Plain carbon steel- The properties of plain carbon steel depend mainly on the carbon percentages and other alloying elements are not usually present in more than 0.5 to 1% such as 0.5% Si or 1% Mn etc.
- The plain carbon steel further may be classified in the following categories:
  - Dead mild steel-upto 0.15% C
  - Low carbon steel or mild steel-0.15 to 0.46% C
  - Medium carbon steel-0.45 to 0.8% C.
  - High carbon steel-0.8 to 1.5% C

Usually in these steels in general higher carbon percentage indicates higher strength.

Steel

Alloy steel- these are steels in which elements other than carbon are added in sufficient quantities to impart desired properties, such as wear resistance, corrosion resistance, electric or magnetic properties.

- Chief alloying elements added are
- nickel for strength and toughness,
- chromium for hardness and strength,
- tungsten for hardness at elevated temperature,
- vanadium for tensile strength,
- manganese for high strength in hot rolled and heat treated condition,
- silicon for high elastic limit,
- cobalt for hardness and
- molybdenum for extra tensile strength.

Non-Ferrous Metals

Non-Ferrous Metals: Metals containing elements other than iron as their chief constituents are usually referred to as on-ferrous metals.

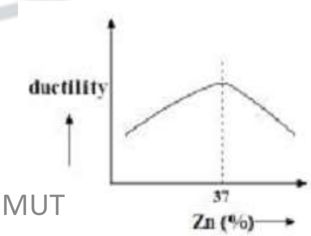
Aluminium- This is the white metal produced from Alumina. In its pure state it is weak and soft but addition of small amounts of Cu, Mn, Si and Magnesium makes it hard and strong. It is also corrosion resistant, low weight and non-toxic.

Duralumin- This is an alloy of 4% Cu, 0.5% Mn, 0.5% Mg and aluminium. It is widely used in automobile and aircraft components.

Y-alloy- This is an alloy of 4% Cu, 1.5% Mn, 2% Ni, 6% Si, Mg, Fe and the rest is Al. It gives large strength at high temperature. It is used for aircraft engine parts such as cylinder heads, piston etc.

Non-Ferrous Metals

- <u>Magnalium</u>- This is an aluminium alloy with 2 to 10 % magnesium. It also contains 1.75% Cu. Due to its light weight and good strength it is used for aircraft and automobile components.
- <u>Copper alloys</u>: Copper is one of the most widely used non-ferrous metals in industry. It is soft, malleable and ductile and is a good conductor of heat and electricity. The following two important copper alloys are widely used in practice.
- <u>Brass (Cu-Zn alloy):</u>It is fundamentally a binary alloy with Zn upto 50% . As Zn percentage increases, ductility increases upto ~37% of Zn beyond which the ductility falls. Small amount of other elements viz. lead or tin imparts other properties to brass. Lead gives good machining quality and tin imparts strength. Brass is highly corrosion resistant, easily machinable and therefore a good bearing material.



Non-Metals

Non-Metals: Non-metallic materials are also used in engineering practice due to principally their low cost, flexibility and resistance to heat and electricity. Though there are many suitable non-metals, the following are important few from design point of view:

- Timber- This is a relatively low cost material and a bad conductor of heat and electricity.
- It has also good elastic and frictional properties and is widely used in foundry patterns and as water lubricated bearings.
- Leather- This is widely used in engineering for its flexibility and wear resistance. It is widely used for belt drives, washers and such other applications.
- Rubber- It has high bulk modulus and is used for drive elements, sealing, vibration isolation and similar applications.

Plastics

Plastics: These are synthetic materials which can be moulded into desired shapes under pressure with or without application of heat.

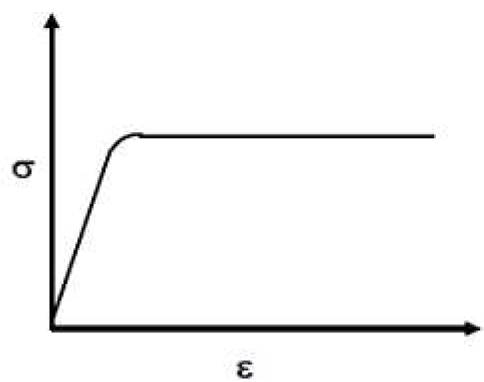
- These are now extensively used in various industrial applications for their corrosion resistance, dimensional stability and relatively low cost.
- There are two main types of plastics:
  (a) Thermosetting plastics
  (b) Thermoplastics

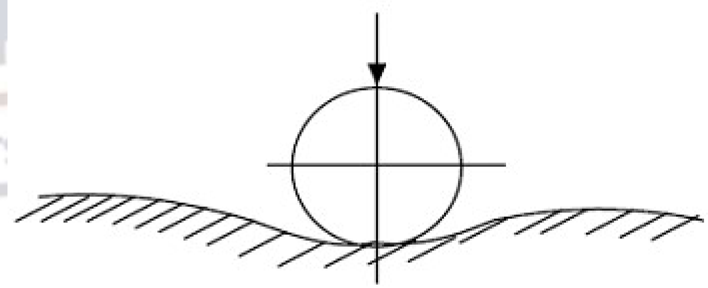
Plastics

- Thermosetting plastics : Thermosetting plastics are formed under heat and pressure. It initially softens and with increasing heat and pressure, polymerisation takes place. This results in hardening of the material. These plastics cannot be deformed or remoulded again under heat and pressure. Some examples of thermosetting plastics are phenol formaldehyde (Bakelite),phenol-furfural (Durite), epoxy resins, phenolic resins etc.
- Thermoplastics: Thermoplastics do not become hard with the application of heat and pressure and no chemical change takes place. They remain soft at elevated temperatures until they are hardened by cooling. These canbe re-melted and remouldedby application of heat and pressure. Some examples of thermoplastics are cellulose nitrate (celluloid), polythene, polyvinyl acetate, polyvinyl chloride (PVC) etc.

Mechanical Properties of Common Engineering Materials

- Elasticity :This is the property of a material to regain its original shape after deformation when the external forces are removed. All materials are plastic to some extent but the degree varies, for example, both mild steel and rubber are elastic materials but steel is more elastic than rubber.
- Plasticity :This is associated with the permanent deformation of material when the stress level exceeds the yield point. Under plastic conditions materials ideally deform without any increase in stress. A typical stress-strain diagram for an elastic perfectly plastic material is shown in the figure. A typical example of plastic flow is the indentation test where a spherical ball is pressed in a semi-infinite body.





Mechanical Properties of Common Engineering Materials

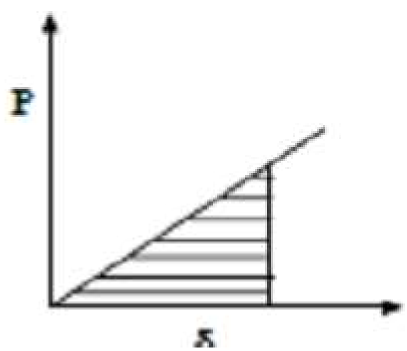
- Hardness: Property of the material that enables it to resist permanent deformation, penetration, indentation etc.
- Size of indentations by various types of indenters are the measure of hardness e.g. Brinnel hardness test, Rockwell hardness test, Vickers hardness (diamond pyramid) test. These tests give hardness numbers which are related to yield pressure (MPa).
- Ductility: This is the property of the material that enables it to be drawn out or elongated to an appreciable extent before rupture occurs.
- The percentage elongation or percentage reduction in area before rupture of a test specimen is the measure of ductility.
- Normally if percentage elongation exceeds 15% the material is ductile and if it is less than 5% the material is brittle. Lead, copper, aluminium, mild steel are typical ductile materials.

Mechanical Properties of Common Engineering Materials

- Malleability : It is a special case of ductility where it can be rolled into thin sheets but it is not necessary to be so strong. Lead, soft steel, wrought iron, copper and aluminium are some materials in order of diminishing malleability.
- Brittleness: This is opposite to ductility. Brittle materials show little deformation before fracture and failure occur suddenly without any warning.
- Normally if the elongation is less than 5% the material is considered to be brittle. e.g. cast iron, glass, ceramics are typical brittle materials.

Mechanical Properties of Common Engineering Materials

- Resilience This is the property of the material that enables it to resist shock and impact by storing energy. The measure of resilience is the strain energy absorbed per unit volume.
- For a rod of length L subjected to tensile load P, a linear load-deflection plot is shown in figure



$$Strain\ energy\ stored = \frac{1}{2} P \times \delta L = \frac{1}{2} \frac{P \times \delta L}{A \times L} \times A \times L = \frac{1}{2} \times \sigma \times \varepsilon \times V$$

$$Strain\ energy\ stored\ \ per\ unit\ volume = \frac{1}{2} \times \sigma \times \varepsilon$$

Mechanical Properties of Common Engineering Materials

- Toughness: This is the property which enables a material to be twisted, bent or stretched under impact load or high stress before rupture. It may be considered to be the ability of
- the material to absorb energy in the plastic zone. The measure of toughness is the amount of energy absorbed after being stressed up to the point of fracture.
- Creep : When a member is subjected to a constant load over a long period of time it undergoes a slow permanent deformation and this is termed as "creep". This is dependent on temperature. Usually at elevated temperatures creep is high.

B.I.S DESIGNATIONS OF THE PLAIN CARBON STEEL

Plain carbon steel is designated according to BIS as follows:

1. The first one or two digits indicate the 100 times of the average percentage content of carbon.
2. Followed by letter “C”
3. Followed by digits indicates 10 times the average percentage content of Manganese “Mn”.

B.I.S DESIGNATIONS OF ALLOY STEEL

Alloy carbon steel is designated according to BIS as follows:

1. The first one or two digits indicate the 100 times of the average percentage content of carbon.
2. Followed by the chemical symbol of chief alloying element.
3. Followed by the rounded off the average percentage content of alloying element as per international standards.
4. Followed by the chemical symbol of alloying elements followed by their average percentage content rounded off as per international standards in the descending order.
5. If the average percentage content of any alloying element is less than 1%, it should be written with the digits up to two decimal places and underlined.

B.I.S DESIGNATIONS OF ALLOY STEEL

(i) 45C8 = Plain carbon steel having average %age of carbon of0.45% and 0.8%Mn.

(ii) Fe250 = Grey cast iron having minimum tensile strength of250 N/mm2

(iii) XT30Ni4Cr2V65 = High speed tool steel having

Average %age content of “C” =0.30%;

Average %age content of “Ni” =4.0%;

Average %age content of “Cr” =2.0%;

Average %age content of “V” =0.65%;

(iv) 37Mn2 = Alloy Steel having

Average %age content of “C” =0.37%;

Average %age content of “Mn” =2.0%;

BASIC CRITERION FOR SELECTION OF MATERIAL

- The basic criterions considered by a designer for the selection of a material for a particular application are:
- Availability of material;
- Cost of material;
- Manufacturing Considerations;
- Material Properties.